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GB 0858332	GB 0803241	GB 0684626
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(58) Field of search
H3X
Selected US specifications from IPC sub-class H03F

(54) A magnetic amplifier

(57) A magnetic amplifier comprises a saturable reactor (10, W_A, W_B) via which alternating current is supplied to a load, a control coil (W_C) to which a direct current control signal (I_C) is applied so as to modulate the said supply of alternating current and capacitor means (C) connected to short circuit alternating currents induced in the control coil (W_C).

The arrangement of the invention enables hysteresis losses, especially those associated with large current loads, to be mitigated.

Two such amplifiers may be used to provide a multiple output power supply (Fig. 6 not shown).

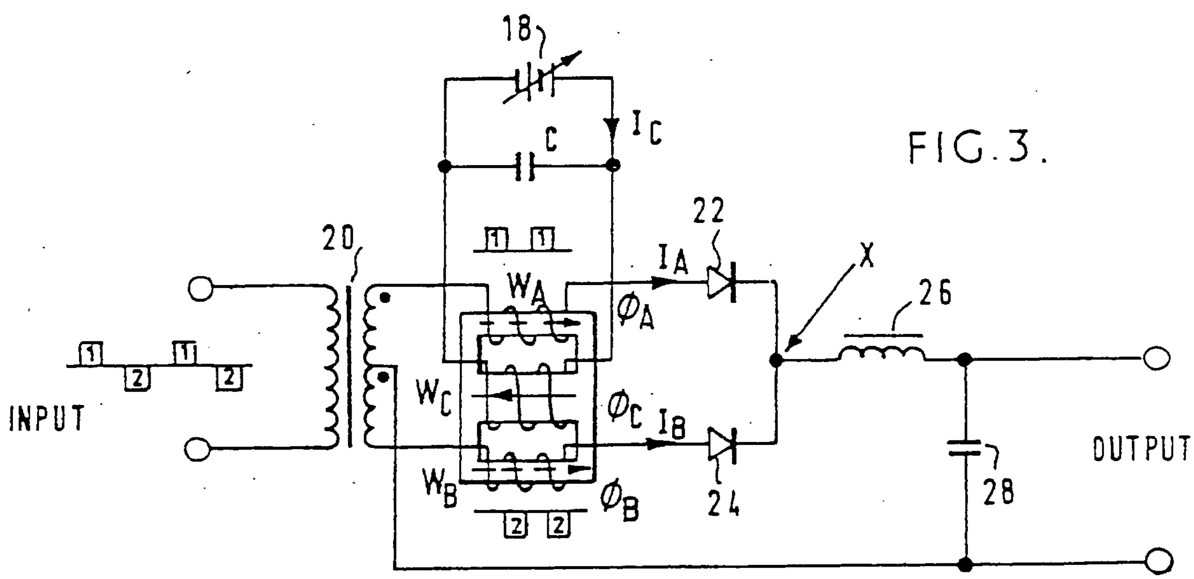

FIG. 3.

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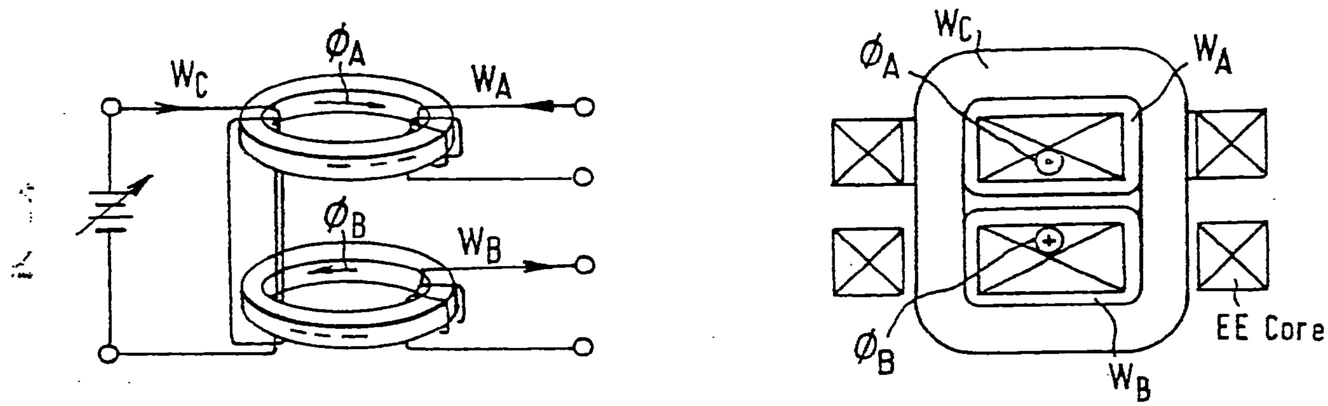

(a) FIG. 1. (b)

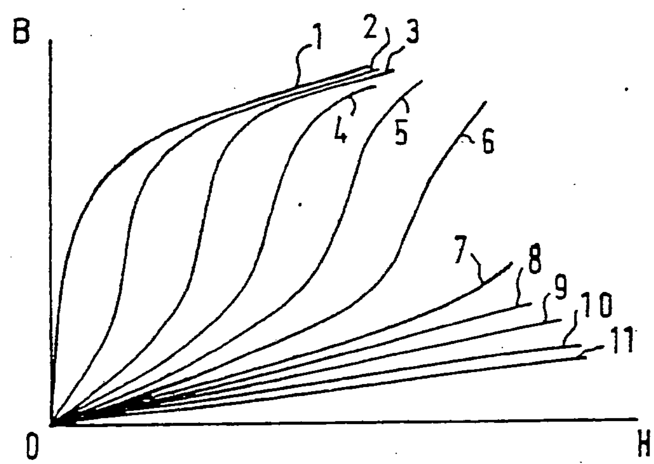

FIG.2.

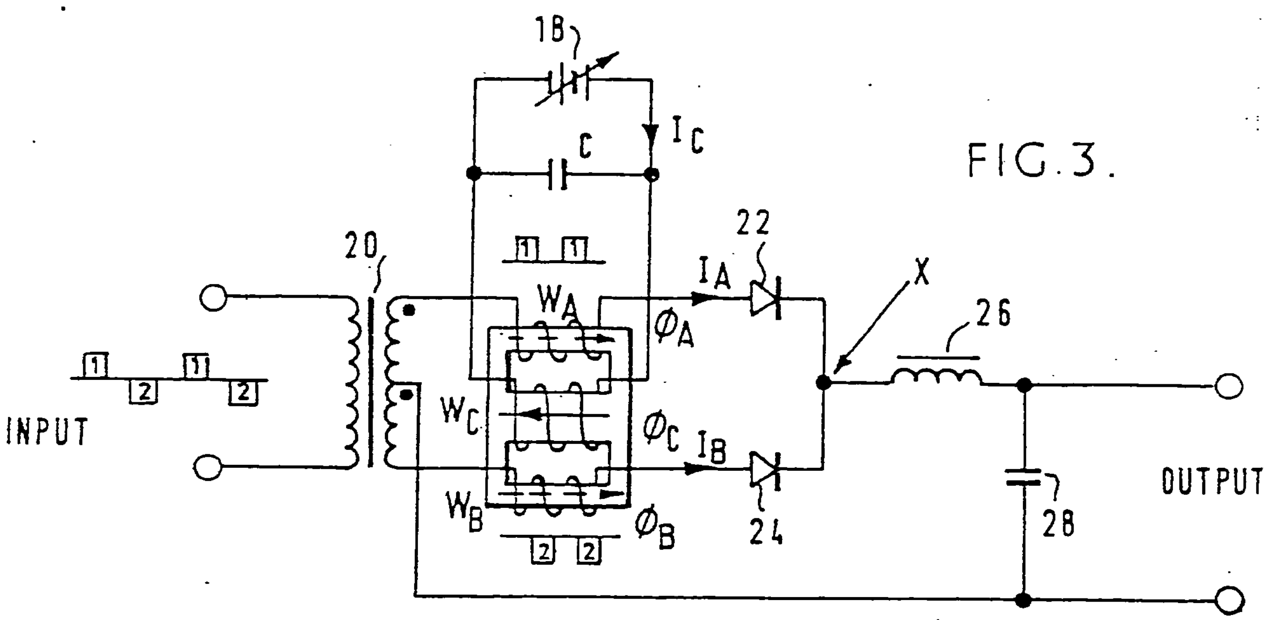

FIG.3.

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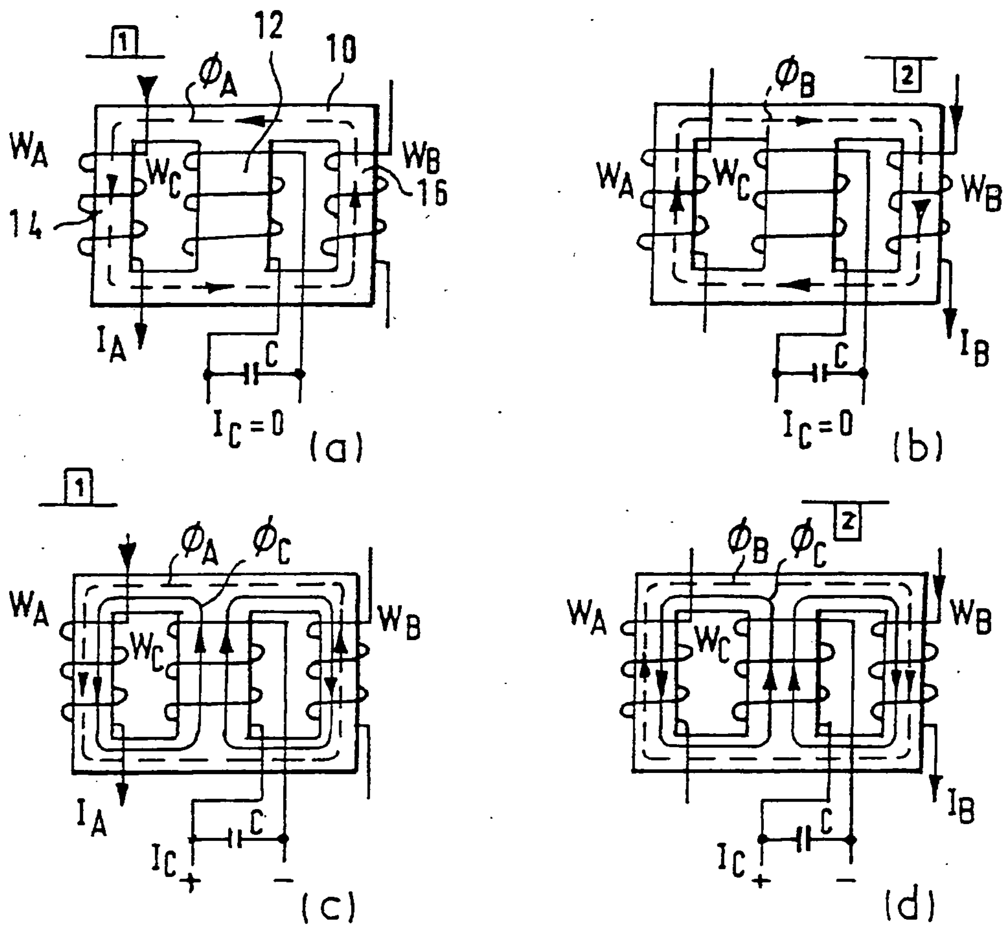

FIG. 4.

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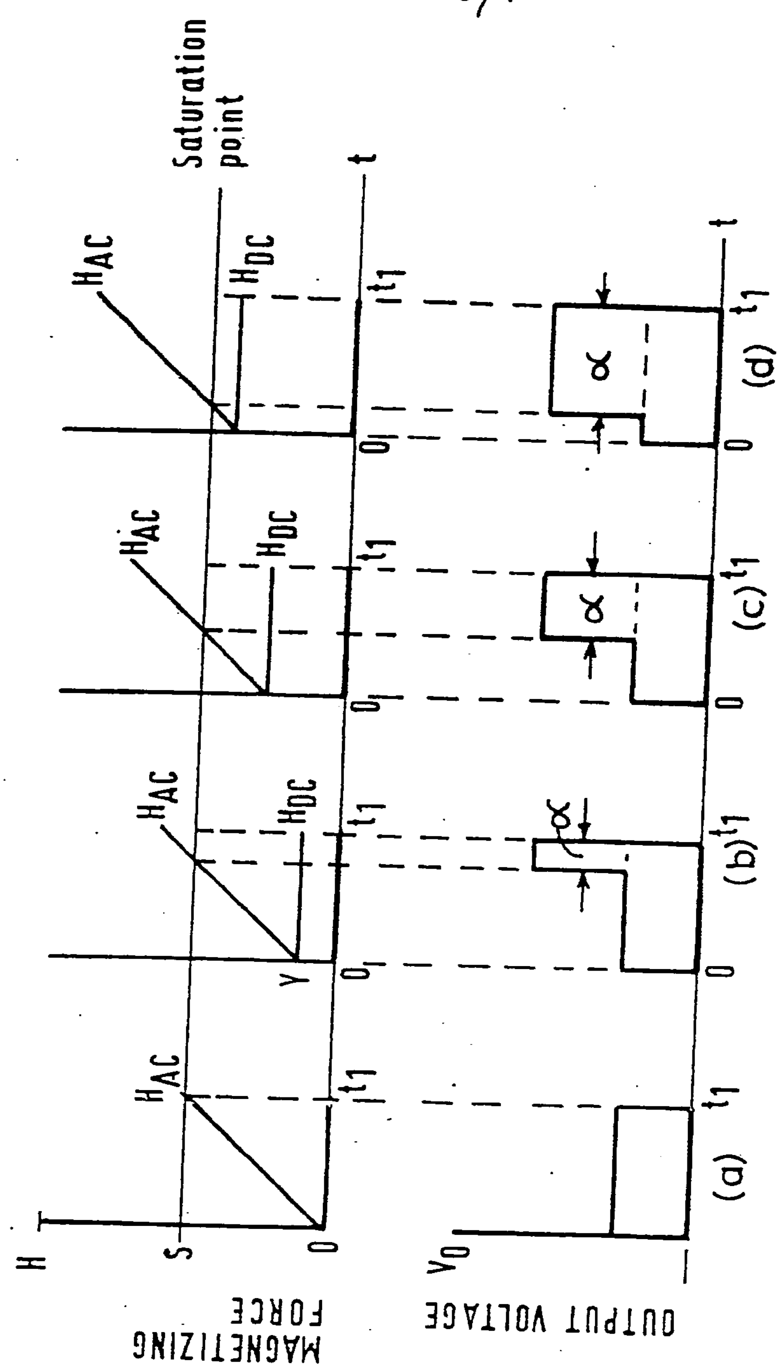

FIG. 5.

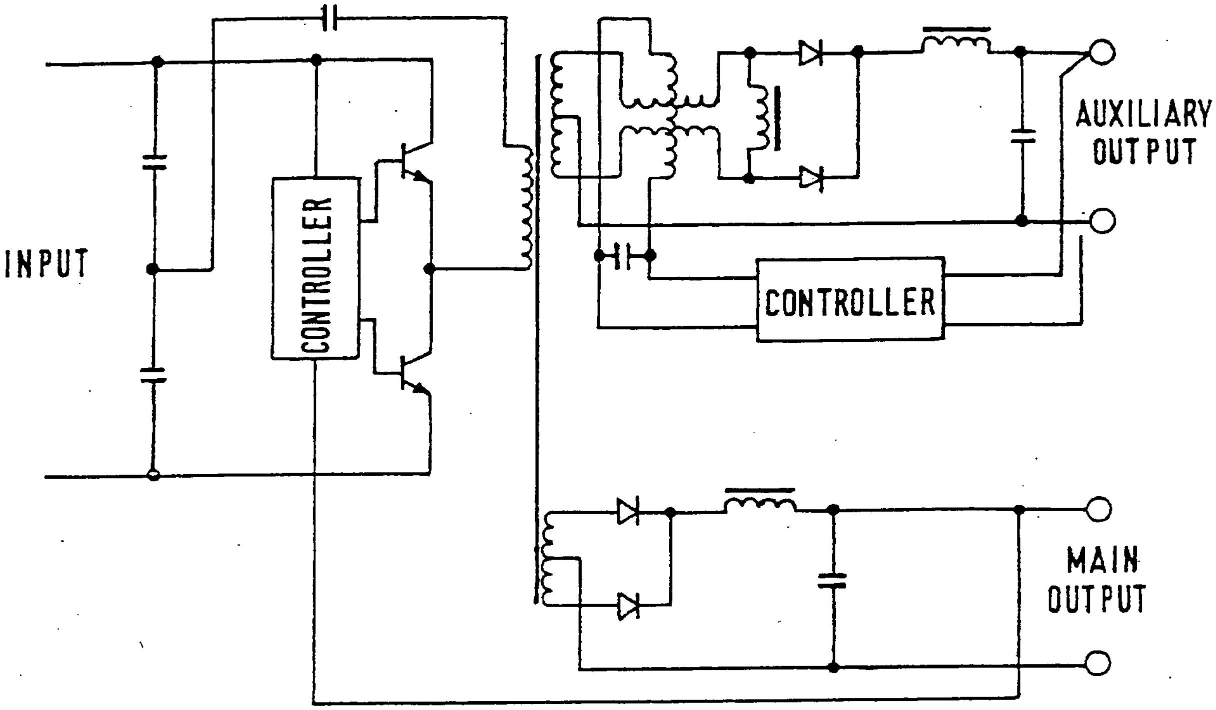
INPUT
CONTROLLER
CONTROLLER
AUXILIARY OUTPUT
MAIN OUTPUT

FIG. 6.

SPECIFICATION

Magnetic amplifier

The present invention relates to an magnetic amplifier and has particular but non-limiting application to power supply switching.

Conventionally, a magnetic amplifier comprises two AC windings wound on separate core segments with a common DC winding encompassing both of the core segments. The AC windings are used to supply alternating current to a load and are connected into a full wave rectifier circuit. Figure 1 of the accompanying drawings illustrates two examples of this conventional arrangement. Figure 1A shows the use of toriodal core segments and the arrangement of figure 1B makes use of a so-called EE core. In both cases the AC windings, W_A and W_B, are wound on respective core segments and current flow through these windings induces respective fluxes ϕ_A and ϕ_B. The fluxes ϕ_A and ϕ_B are out of phase with each other and this results in the net EMF induced in the DC winding W_c being zero. A DC control current is applied to winding W_C and this establishes a flux ϕ_C which alters the inductive reactance of the magnetic amplifier. Flux ϕ_C effectively alters the magnetic permeability of the arrangement and this affects the hysteresis or B-H curve of the core segments as indicated in figure 2. Figure 2 illustrates the effect of increasing the DC current applied to the control winding W_C with curve 1 showing the condition when the control DC current is zero, curve 11 showing the condition when the DC control current is maximum and curves 2-10 showing intermediate stages.

A major disadvantage of known magnetic amplifiers is that the control of a large load current establishes a high residual magnetism in the core which significantly degrades the perforamance of the amplifier. That is, there is a high hysteresis loss and possible distortion of the waveform.

With a view to mitigating the above described disadvantage, the present invention provides a magnetic amplifier comprising a saturable reactor via which alternating current is supplied to a load, a control coil to which a direct current control signal is applied so as to modulate the said supply of alternating current and capacitor means connected to short circuit alternating currents induced in the control coil.

The arrangement of the present invention enables input into the magnetic amplifier to be in the form of a pulsed DC current in which alternate pulses are of opposite polarity. Such an input can be arranged so as to reduce significantly hysteresis losses within the core of a magnetic amplifier and the capacitor means ensure that induced EMF's do not damage the DC source supplying the control coil.

Embodiments of the invention will now be described by way of example only and with reference to the accompanying drawings, in which:

Figure 1 illustrates two arrangements of known magnetic amplifiers, as described above;

Figure 2 is a B-H curve illustrating the effect of applying a DC current to the control coil of a magnetic amplifier;

Figure 3 is a schematic circuit diagram showing the application of one embodiment of the present invention;

Figures 4(a)-(b) are helpful in explaining operation of the magnetic amplifier shown in figure 3;

Figure 5 is a graphical representation of the relationship between DC control current and output voltage of the magnetic amplifier shown in figure 3; and

Figure 6 is a circuit diagram illustrating a particularly useful application of the present invention.

As can be seen from figures 3 and 4 of the accompanying drawings, one embodiment of the invention comprises a magnetic core 10, two AC windings W_A and W_B, a DC control winding or coil W_C and capacitor C connected across the terminals of winding W_C. The core 10 has a cross-section in the shape of a hollow rectangle with a central member 12 parallel to two sides of the rectangle and dividing the interior thereof into two equal parts. The central member 12 and the two parallel sections 14 and 16 of the core constitute three limbs each of which carries a respective winding. The AC coils W_A and W_B are wound on respective outer limbs 14 and 16 and the control winding W_C is carried by the central limb 12. It will be appreicated that this arrangement differs from the known arrangements, as exemplified in figure 1, in that only a single core segment is provided and the control winding W_C does not encompass the two AC windings W_A and W_B. More importantly, the arrangement of the present invention is provided with capacitor C applied across the terminals of the control winding W_C.

The provision of capacitor C ensures that winding W_C is effectively short circuited with respect to AC currents. Consequently, any EMF's induced in winding W_c as a result of the fluxes ϕ_A and ϕ_B established by windings W_A and W_B will short circuit via capacitor C. Thus, the DC source 18 supplying control winding W_C is protected from damage by EMF's induced in winding W_C. This feature enables a pulsed DC input to be applied to the magnetic amplifier. It is to be noted that the known magnetic amplifiers require cancellation of EMF's induced in control winding W_C by the difference in phase of fluxes ϕ_A and ϕ_B.

Figure 3 of the accompanying drawings illustrates use of an embodiment of the present

invention in a full wave rectifier circuit. Windings W_A and W_B each have an input connected to respective terminals of a transformer 20 with the outputs of the windings W_A and W_B being connected to respective diodes 22 and 24. Output from both of the diodes 22 and 24 are applied to a common terminal X at the input of a smoothing choke 26. Output from the full wave rectifier is taken between output from choke 26 and a central tap on transformer 20. A capacitor 28 is connected across the output terminals of the rectifier in order to provide additional smoothing of the output signal.

A pulsed DC input is applied to transformer 20 with alternate pulses having an opposite sense of polarity, as indicated by reference numerals 1 and 2. Since windings W_A and W_B are connected to opposite ends of the transformer output coil, wingings W_A and W_B conduct alternatively under the described input signal. Thus, the pulses marked with reference numeral 1 pass through winding W_A and the pulses marked with reference 2 pass through winding W_B. Consequently, fluxes ϕ_A and ϕ_B are established and respective currents I_A and I_B flow into diodes 22 and 24.

The effect of applying a DC control current I_C to winding W_C can best be understood with the aid of figures 4(a)-(d). When the control current I_C is zero, as shown in figures 4(a) and 4(b), pulses 1 pass through winding W_A and establish flux ϕ_A and output current I_A. Flux linkage through core 10 is essentially in a anticlockwise direction as shown in figure 4a and substantially no flux passes through central limb 12. Similarly, pulses 2 pass through winding W_B establishing flux ϕ_B and output current I_B. In these circumstances, as shown in figure 4(b) flux within core 10 circulates in a clockwise direction and again there is substantially no flux flowing through central limb 12. If, however, a DC current I_C is applied to winding W_C then the conditions are altered as shown in figures 4(c) and 4(d). Figure 4(c) corresponds to figure 4(a) and figure 4(d) corresponds to figure 4(b). Control current I_C f lowing in winding W_C establishes a flux ϕ_C. Flux ϕ_C flows through central limb 12 of core 10 and through the outer limbs 14 and 16 thereof. Effectively, flux ϕ_C flows in a clockwise direction through the circuit including limbs 12 and 16 and flows in an anticlockwise direction in the circuit including limbs 12 and 14. It will be seen that the effect of flux ϕ_C is to reinforce fluxes ϕ_A and ϕ_B in the alternate conditions of pulses 1 passing through winding W_B and pulses 2 passing through winding W_B. In addition, at the same time as reinforcing flux ϕ_A, flux ϕ_C acts against the flux flowing in limb 16. Similarly, while enforcing flux ϕ_B, flux ϕ_C acts against the flux flowing within limb 14. The overall effect of control current I_C is to regulate the magnetic saturation of limbs 14 and 16 of core 10. This has the direct effect of increasing the amplitude of pulses 1 and 2 as they pass through the magnetic amplifier.

The effect of control current I_c can be further explained with reference to figure 4 of the accompanying drawings. Figure 4 illustrates both magnetising force H against time t and output voltage V_O against time t. The output voltage V_O is that which occurs at point X shown in figure 3 and four different conditions are shown in graphs (a)-(b). These four conditions relate to different values of the control current I_C. As shown in figure 4(a), the control current I_C is zero and there is therefore no DC magnetising force H_{DC}. The AC magnetising force H_{AC} ramps from time zero to time t_1 which represents the duty cycle of the input signal. The alternating current magnetising force H_{AC} fails to reach or only just reaches a value S which corresponds to the saturation point of the respective limb of core 10. In the circumstances depicted in figure 4(a) the inductive reactance is very high and consequently the output voltage V_O is low.

The effect of applying a relatively small DC control current I_C is illustrated in figure 4(b). Current I_C establishes a magnetising force H_{DC} which effectively produces a magnetising force offset Y such that the AC magnetising force H_{AC} does not ramp from zero but from the offset value Y. Consequently, the applied magnetising force exceeds the saturation value S within time t_1. As soon as the saturation point has been exceeded, the inductive reactance becomes very low and therefore the output voltage V_O rises rapidly. The portion of time period t_1 for which the applied magnetising force exceeds the saturation point may be considered as the conduction angle α, as shown in figure 4. Figures 4(c) and 4(d) show the effect of subsequent increases in the control current I_C. Thus, it can be seen that the conduction angle of the output voltage is controlled by the control current I_C.

The explanation given with reference to figure 4 and taken in conjunction with the circuit shown in figure 3 demonstrates that variation of pulse width and/or amplitude of the input signal to the full wave rectifier is automatically compensated for since the conduction angle α will vary resulting in maintenance of a constant output voltage.

Figure 6 illustrates a practical application of an embodiment of the present invention. Figure 6 is a circuit diagram of a multiple output power supply employing a magnetic amplifier Post Regulator. The regulator is implemented in accordance with the arrangement shown in figure 3. In fact, both of the controllers shown in figure 6 are implemented in accordance with the arrangement shown in figure 3.

CLAIMS

1. A magnetic amplifier comprising a saturable reactor via which alternating current is

supplied to a load, a control coil to which a direct current control signal is applied so as to modulate the said supply of alternating current and capacitor means connected to short circuit alternating currents induced in the control coil.

2. A magnetic amplifier as claimed in claim 1, wherein the saturable reactor includes two coils.

3. A magnetic amplifier as claimed in claim 2, wherein all three coils are wound on a common core.

4. A magnetic amplifier as claimed in claim 3, wherein the core comprises three limbs each having a respective coil wound thereon.

5. A magnetic amplifier substantially as hereinbefore described and as illustrated in figures 3-5 of the accompanying drawings.

6. A full wave rectifier comprising a magnetic amplifier as claimed in any preceding claim.

7. A multiple output power supply comprising a magnetic amplifier as claimed in any of claims 1 to 5.

8. A multiple output power supply substantially as hereinbefore described with reference to and as illustrated in figure 6 of the accompanying drawings.

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